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EVALUATION OF MAINTAINABILITY ENHANCEMENT FOR TCP/TSP REVISION --ETC(U)
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NAVAL POSTGRADUATE SCHOOL

Monterey, California

EVALUATION OF MAINTAINABILITY ENHANCEMENT
FOR TCP/TSP REVISION 6.0 UPDATE .20

Norman F. Schneidewind

February 1982

Final Report: 1 Jan 80 to 1 Jan 82

Approved for public release; distribution unlimited

Prepared for:
The Trident Command and Control Systems Maintenance Agency
Newport, Rhode Island

NAVAL POSTGRADUATE SCHOOL
Monterey, California

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The work reported herein was supported by the Trident Command and Control Systems Maintenance Agency.

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS
BEFORE COMPLETING FORM

1. REPORT NUMBER
NPS54-82-004

2. GOVT ACCESSION NO.
AD-A114 496

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
EVALUATION OF MAINTAINABILITY ENHANCEMENT
FOR TCP/TSP REVISION 6.0 UPDATE .20

5. TYPE OF REPORT & PERIOD COVERED
Final Report
1 Jan 80 to 1 Jan 82

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Norman F. Schneidewind

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Postgraduate School
Monterey, California 93940

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
N4216680WR00007

11. CONTROLLING OFFICE NAME AND ADDRESS
Trident Command and Control Systems
Maintenance Agency
Newport, Rhode Island 02840

12. REPORT DATE
22 February 1982

13. NUMBER OF PAGES
41

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Software maintenance	SECNAVINST 3560.1
Software maintainability	FIPS PUB 38
Software standards	MIL-STD 1679
Traceability	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A system of documentation which was designed to aid programmers of the Command and Control System Maintenance Agency (CCSMA) in maintaining the Trident Command and Control System software was evaluated. This system is called "Maintainability Enhancement for TCP/TSP Revision 6.0 Update .20" or simply 6.0/.20. It is essentially a hierarchical method of charting software procedures and the relationship between procedures. The difficulty of trying to overlay a structured documentation technique on programs which are inherently non-structured (written in low-level language and patched) is

discussed. Discrepancies which arose between the newly constructed charts and the original listings are highlighted. A conclusion of this study is that rather than improving clarity, applying structured documentation to non-structured programs may result in the opposite effect--incomplete, inconsistent, and ambiguous documentation--because a hierarchical format cannot adequately represent a non-hierarchical program.

SECNAVINST 3560.1 and MIL-STD 1679 (Navy) are considered by CCSMA to be relevant documents for maintenance purposes. Therefore, the documentation system was checked for conformance with applicable sections of 3560.1 and 1679. In addition, the documentation system was compared with applicable sections of FIPS PUB 38, published by the National Bureau of Standards. Although officially FIPS PUB 38 applies to ADP and not to embedded computer systems, it provides good guidelines for program documentation and maintenance. It was found that 6.0/.20 does not include coverage of many of the applicable sections of the three documents.

SUMMARY

Trident CCSMA requested the Naval Postgraduate School to evaluate the "Maintainability Enhancement for TCP/TSP Revision 6.0 Update .20," referred to as 6.0/.20. The approach for accomplishing this task was to compare 6.0/.20 for compliance or conformity with applicable sections of SECNAVINST 3560.1, FIPS PUB 38, AND MIL-STD 1679. In addition, a sample of 6.0/.20, Volume 2, was examined in some detail for its usefulness as a software maintenance tool in terms of consistency, completeness, understandability, and absence of errors. Many suggestions for improvement have been made.

Our conclusions are that 6.0/.20:

- Does enhance maintainability. However, we believe listings alone, even if they are structured, are inadequate for maintenance purposes.
- Does not include coverage of significant applicable items called for in 3560.1, FIPS PUB 38, and 1679.
- Appears to be incomplete and to contain a moderate amount of inconsistencies, ambiguities, and errors.
- Could provide an excellent software maintenance tool if its quality were improved in accordance with the suggestions made in this report.

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LIST OF FIGURES

I. INTRODUCTION

A. Purpose

Trident CCSMA has requested the Naval Postgraduate School (NPS) to evaluate the "Maintainability Enhancement for TCP/TSP Revision 6.0 Update .20" documents, subsequently referred to as 6.0/.20, with respect to its usability for maintaining Trident Command and Control System software.

B. Approach

It is understood that one of the governing documents for the production and use of Trident software is "Department of the Navy Tactical Digital Systems Documentation Standards," SECNAVINST 3560.1, 8 August 1974. Therefore, it was deemed appropriate to use this standard as one means of evaluating the subject documents. It was felt that, as a minimum, documentation used on the Trident project should meet the applicable sections of this standard. However, recognizing that this standard was issued many years ago and that the field of software engineering has evolved in the interim, additional criteria which reflect more modern software design and maintenance techniques were used in the evaluation.

The part of 3560.1 which appears to be most applicable to maintenance is the Program Description Document, pages 2-137 to 2-152. As stated in this document, its purpose, in part, is the following: "As a detailed compendium of the subprogram structure, the Program Description document will serve as the essential instrument for subsequent use by operational, maintenance, and contractor personnel diagnosing troubles, making adaption changes, designing and implementing modifications to the system, and introducing or adding new subprogram functions to the completed program" (underlining added by the author).

Another means of evaluation was with respect to the publication "Guidelines for Documentation of Computer Programs and Automated Data Systems," National Bureau of Standards, Federal Information Processing Standards Publication 38 (FIPS PUB 38), February 15, 1976. As stated in FIPS PUB 38, its purpose is the following: "These guidelines provide a basis for determining the content and extent of documentation for computer programs and automated data systems. Software development phases and related document types are identified, several examples of documentation options are given, and content guidelines for ten document types are provided." Although, officially, this guideline is not applicable to Trident software because it was written to apply to ADP systems under the provisions of Public Law 89-306 (Brooks Bill), which excluded embedded computer systems, it is of technical interest because it is one of the few Federal Government software guidelines which covers program maintenance.

As stated in FIPS PUB 38, "The purpose of the Program Maintenance Manual is to provide the maintenance programmer with the information necessary to understand the programs, their operating environment, and their maintenance procedures." The Program Maintenance Manual is described on pages 45-47 of FIPS PUB 38.

It was also considered important to examine 6.0/.20 with respect to the applicable sections of MIL-STD 1679 (Navy), 1 December 1978, the Navy's Military Standard for Weapon System Software Development. The applicable section of 1679 is primarily 5.11 Configuration Management, pages 23-24.

C. Scope

In order to ensure good software maintainability, it is necessary to use sound programming methodology and procedures, as well as provide good documentation. It is difficult to evaluate the quality of documentation and not also consider the quality of the product that has been documented, because good documentation of non-structured programs which contain machine language code, although of some benefit, will not result in good software maintainability, nor will good documentation of highly patched programs allow software to be easily maintained. In other words, if programs are inherently difficult to change and understand and may not have been designed with maintainability in mind, documentation may only make a marginal contribution to the improvement of maintainability. Thus, this project poses a dilemma because we have been asked to review and evaluate documentation for programs which are non-structured, contain significant amounts of machine language code, and are highly patched. It is understandable that this is the case, since the programs were designed prior to the availability of a mature structured programming methodology and high level languages for tactical system software development. In addition, although machine language patching is generally considered to be undesirable, for certain administrative and contractual reasons it is a prevalent practice in Navy embedded computer software development. The argument can be made that, because of these practices, good documentation is even more important in this environment than it would be in those situations where the use of structured programming and high level languages provide a degree of self-documentation. Accordingly, the scope of this paper will be limited to evaluating the adequacy of 6.0/.20 for maintaining the TCP/TSP software, ignoring what is perhaps the more fundamental maintenance issue of the adequacy of the underlying software.

A major assumption of this study which affects its scope is that the 6.0/.20 documentation is to be evaluated independently of the program listings. It is noted that listings are not included in the version of 6.0/.20 dated 29 September 1979, although these were included in a prior version (undated). Quoting from Volume 1 of the version dated 29 September 1979, "The primary goal is to improve this software's maintainability by making the programs and their patches understandable and visible in a single *simplified form*," (*underlining* added by the author). The implication which has been derived based on the above statement and the fact that the listings are not included in the latest version, is that 6.0/.20 is to be used for maintenance purposes primarily on a stand-alone basis with listings utilized as a secondary source of information. This interpretation is critical with respect to some of the results obtained in this study, because certain deficiencies in 6.0/.20, which are noted later in this report, regarding such items as data design, tables and indexes, are not addressed by 6.0/.20 but are covered in the listings. If it was the intent to use the listings with 6.0/.20 in a coordinated fashion, it would be helpful to provide a detailed cross-referencing between the two. A method for accomplishing this cross-referencing is suggested in a later section. The scope of this report is limited to considering 6.0/.20 as an independent tool for maintenance which does not rely extensively on the use of program listings. However, since the flowcharts are based on the program logic, as expressed in the listings, it was necessary to make extensive reference to the listings in this report in order to understand and evaluate 6.0/.20. In fact, a result of this analysis was the conclusion that the two mediums should be used as an integrated documentation package and not in isolation.

II. EVALUATION OF 6.0/.20

A. With Respect to SECNAVINST 3560.1, Program Description Document, Pages 2-137 to 2-152.

The following 3560.1 pages and sections are covered by 6.0/.20:

Page	Section	Title
2-141	1.	Scope
2-141	2.	Applicable Documents
2-142	3.	Requirements
2-142	3.1	Subprogram Detailed Description
2-143	3.2	Subprogram Flow Diagrams
2-148	3.6	Conditions for Initiation
2-149	3.8	Interface Description

The 3560.1 pages and sections which apparently are not covered by 6.0/.20 are identified below. It is possible that these sections are not applicable to certain volumes of 6.0/.20. However, the named missing sections were not found in any of the 6.0/.20 volumes for which copies were provided to NPS, so it is assumed that it was not intended to include these sections in 6.0/.20. A brief description of the intended contents of the missing sections as specified by 3560.1 is given:

Page	Section	Title	Contents
2-144	3.3	Subprogram Data Design	General summary description of the subprogram data base.
2-144	3.3.1	Tables	Detailed description of each table used in the subprogram data base: a. Table name. b. Purpose and type. c. Size and indexing procedure. d. Structure and bit layout.

2-145	3.3.2	Variables	Detailed description of each variable used in the subprogram data base: a. Variable name. b. Purpose. c. Structure and bit layout.
2-145	3.3.3	Flags	Detailed description of each flag used in the subprogram data base: a. Flag name. b. Purpose and status. c. Structure and bit layout.
2-145	3.3.4	Indexes	Technical description of each index used in the subprogram data base: a. Index name. b. Purpose.
2-146	3.3.5	Common Data Base Reference	Complete list of all references to local and common data base items and the location of each reference.
2-146	3.4	Input/Output Formats	Brief description and graphic (sample) representation of each input and output message, card format, tape format, etc. processed by the subprogram.
2-148	3.7	Subprogram Limitations	Summary of any known or anticipated limitations of the subprogram.
2-149	4.	Quality Assurance Provisions	Reference to all applicable test plans and procedures that have been used for verification of the subprogram. (6.0/.20 should reference the Trident Test Specification Requirements and Test Procedures which are described in Refs. 1 and 2.)

NOTE: It was not possible to determine whether Section 3.5 Required System Library Subroutines was covered by 6.0/.20 because it was not known whether library subroutines were used.

B. With Respect to FIPS PUB 38, Program Maintenance Manual , Pages 45-47

The following Program Maintenance Manual sections are covered by 6.0/.20:

Section	Title
1.	General Information
1.1	Summary
1.2	Environment
1.3	References
2.	Program Descriptions
2.1	Program Identification
2.1.1	Problem and Solution Method
2.1.2	Input (description of)
2.1.3	Processing (logic, linkages, error handling)
2.1.4	Output (description of)
2.1.5	Interfaces
2.1.7	Run Description
3.	Operating Environment
3.2	Support Software
3.2.1	Operating System
3.2.2	Compiler, Assembler

The Program Maintenance Manual sections which apparently are not covered by 6.0/.20 are identified below. The caveats that were stated relative to 3560.1 also apply to this section.

Section	Title	Contents
2.1.2	Input	Layout, medium, codes, units of measurement, format, range of values or reference to a data element dictionary.
2.1.3	Processing	Variables, constants, restrictions, switches, flags.
2.1.4	Output	Layout, medium.
2.1.6	Tables	Identification, content, location, structure, purpose.
3.1	Hardware	Equipment required for operation of system and for each program.
3.3	Data Base	Description of data bases used or reference to a data element dictionary (codes, units of measurement, format, range of values).
4.	Maintenance Procedures	
4.1	Programming Conventions	Identification and descriptions.
4.2	Verification Procedures	Description of procedures to check the performance of programs, in general and following modification. Reference to test data and testing procedures. (6.0/.20 should reference the Trident Test Specification Requirements and Test Procedures which are described in Refs. 1 and 2).
4.3	Error Correction Procedures	Description of error conditions, sources and procedures for correction. (6.0/.20 should reference the Trident CCS Problem Reporting and Modification Systems which are described in Refs. 1 and 2.)
4.4	Special Maintenance Procedures	Description of special procedures which change with time or conditions (e.g., change of parameters, algorithms).
4.5	Listings and Flowcharts	Information about how to obtain copies of listings and flowcharts.

NOTE: It is possible that Section 3.3 Data Base is not applicable to any of the programs documented by 6.0/.20.

C. With Respect to MIL-STD 1679 (Navy), Configuration Management, Pages 23-24

The following configuration management sections of 1679 are covered by 6.0/.20:

Section	Title
5.11	Configuration Management
5.11a	Positive identification of all program components
5.11.1	Configuration Identification
5.11.1.1	Baselines
5.11.1.2	Documentation Identification
5.11.1.2a	Component
b.	Purpose
c.	Baseline
d.	Serial, edition and change status

The sections which apparently are not covered by 6.0/.20 are identified below. The caveats that were stated relative to 3560.1 also apply to this section.

Section	Title
5.11b	Treatment of proposed changes to components under configuration control.
5.11c	Implementation of approved changes and dissemination of corrected documentation and program changes.
5.11d	Recording of status of all proposed changes.
5.11e	Verification of change control, identification and status account of documentation and program materials.

5.11.2	Configuration Control	Procedures for formal control of all documents, program materials and support library shall be established.
5.11.2.1	Software Changes	Proposed changes to software which is under configuration control shall be submitted to the appropriate software configuration control boards.
5.11.2.2	Documentation Changes	Procedures for controlling preparation and dissemination of changes to documentation shall be developed.
5.11.2.3	Software Configuration Control Boards	Each baseline plus approved changes from those baselines shall be under the formal control of a responsible board.
5.11.3	Configuration Status Accounting	Procedures to enable the generation of periodic status reports on all components under configuration management shall be established.

With respect to the above sections, 6.0/.20 should reference the Trident CCS Problem Reporting and Modification Systems and the Configuration Management System which are described in Refs. 1 and 2.

III. OTHER COMMENTS

The following comments pertain to 6.0/.20 Volume 2, using it as an example.

A. Functional Description, on Pages 3-1 to 3-3

1. The discussion would be more meaningful if it were keyed to the hierarchical structure diagrams and to the flowcharts. For example, definitions and descriptions of pertinent interrupts should be provided, including important symbolic addresses which are utilized. This information and the interrupt numbers should be related to the diagrams.

2. Sub-headings for the various sections, such as "Interrupt Handling," would make the text more readable.

3. Some typos were observed which affect understandability. For example, the fifth line in the second paragraph on page 3-3.

4. Although this comment does not concern quality of documentation, it was noted on page 3-2 that the control memory test for all zeros and all ones should be preceded by setting the relevant portions of main memory to non-zero and non-one data, respectively, prior to the transfer of control memory to main memory.

B. Hierarchical Structure Diagrams

1. Hierarchical structure diagrams and flowchart symbols should be defined at the beginning of each volume. It is not clear that these diagrams strictly adhere to ANSI standards (see Reference 3).

2. A consistent hierarchical structure box numbering system should be utilized which would indicate at a glance two important pieces of information: the function (e.g., "Periodic Entry") to which the routine belongs, and the level of the routine within the function. This scheme is shown on the accompanying hierarchical structure diagrams, which were reproduced from Volume 2 (pages 4-4 to 4-8). The left digit is function number, the middle digit is level number and the right digit is routine number for a given level and function. Level numbers start at "1" and increase from top to bottom; routine numbers start at "1" and increase from left to right. These numbers should be referenced to the pertinent flowcharts, as shown on the accompanying diagrams (pages 4-9 to 4-12 of Volume 2). As a means of tying together hierarchical structure diagrams, flowcharts and listings, the identification numbers could be appended to the listings as shown on the reproduced CMS-2 Assembler listing (page 6 of listing), which is attached. Two columns are utilized: one is the "At" column corresponding to lines with labels; the other is the "To" column corresponding to lines with transfer of control. Perhaps these identifiers could be punched and printed in formatted columns as part of the "Comments" field. A further help would be to sort source statements by the "At" column and to indent based on the middle digit. This would provided a structured listing of an entire function in contiguous locations.

3. Although it is not a fault of the flowcharting process, it was observed that there is a similarity of labels (e.g., CTPRE and CTPER). This could lead to error in software maintenance.

C. Flowcharts

1. The entry to a flowchart page should be annotated with the flowchart page numbers which are associated with the source(s) of the transfer of control and the exit(s) from a flowchart page should indicate the page number(s) which are associated with the destination(s) of the transfer of control. This is shown on the attached pages 4-9 to 4-12 of Volume 2.

2. There is no loop back to CTPER1 on page 4-9 of the flowcharts, as indicated by the JBNZ instruction at line 223 on page 6 of the listing. Instead the box at the bottom of page 4-9 reads: "Repeat Data Pattern Test Using 'IWC' Control Word." Similarly there is no loop back to CTPER2 on page 4-10 nor loop back to CTPER3 on page 4-11, as shown by line 230 and 238, respectively, on the listing. This method of presentation seems to mask an important characteristic of the program logic.

3. There seem to be discrepancies between flowcharts and listings. For example, the second box from the bottom of page 4-11 figure 4.3 refers to IWC. Page 6, lines 243 and 244 refer to ICW. The box in the flowchart also refers to "Set Up Class IV," while line 243 on the listing refers to Class II.

D. Interpretation of Hierarchical Structure Diagrams

1. Using Volume 2 as an example, it appears that the hierarchical structure diagrams are not totally accurate in portraying program logic. For example, the following discrepancies were noted between hierarchical structure and the listings:

a. With respect to page 4-5, figure 4.2, CTPER is shown superior to all other routines on this chart, yet an analysis of the listing reveals that CTPER only happens to be the first label in this series of code and its only paths to other labels are to CTPER1 and CTPERROR. The latter reference brings to light another discrepancy. CTPER does have a conditional branch to CTPERROR in the listing (line 219), but according to figure 4.2, there is no path between these routines. Wtih respect to figure 4.2, the listings indicate the following access paths among routines:

- CTPER accesses CTPER1 and CTPERROR.
- CTPER1 accesses CTPER2 and CTPERROR.
- CTPER2 accesses CTPER3 and CTPERROR.
- CTPER3 accesses CTRTN and CTPERROR.

Thus, a more accurate picture of this logic is shown in the diagram labeled "Revised Figure 4.2 CT Hierarchical Structure (2 of 5)." It should be noted that in this diagram the horizontal lines indicate paths between adjacent code segments that are in the same module and vertical lines indicate paths involving transfer of control. Also, the arrows, from left to right and from top to bottom, indicate the general direction of control flow. In large measure the "routines" which have been shown as hierarchical structures boxes in Volume 2 are simply labels in a segment of code. This has been pointed out in Volume 2 on page 4-3. The difficulty in constructing the hierarchical structure from program listings is that by definition, the diagrams are supposed to indicate hierarchy, i.e., superior-subordinate relationships, and programs designed using a top-down approach. Since the programs were not written this way, the imposition of a hierarchical structure on a coding format that is inherently non-structured will lead to incompatibilities between diagrams and listings, unless great care is exercised in performing the translation.

b. Pages 4-7 and 4-8, figure 4.2, show CTKLAS2 as having access to CTKLASY. The listing indicates that this actually occurs via CTKLIPI (lines 314 and 342), which is not listed as a routine in figure 4.1, page 4-2 of volume 2. CTKLIPI also has a path to CTARITH via CTKL2XIT at line 349. Page 4-8 also shows no path between CTKAS2I and CTKLASY*. However, the listing shows this path to exist. This condition was verified by consulting the CMS-2 Assembler List Cross Reference Table. One of these references to CTKLASY occurs from the same routine.

- Pages 4-7 and 4-8 show no path between CTKLAS2 and CTKLAS2Z. However, line 335 on the listing shows that this label is contained within routine CTKLAS2.

- Page 4-8 shows no path between CTKLASY and CTKLAS2J. A check of the List Cross Reference Table revealed that this path does exist; this reference to CTKLAS2J occurs at line 430. However, this path is used only when a 4 stop condition does not exist.

- Taking the above difference into account, page 4-8 has been redrawn and is labeled as "Revised Figure 4.2 CT Hierarchical Structure (5 of 5)." Again, the procedure was to use horizontal arrows (going into side of box) to indicate adjacent code segment relationships (e.g., between CTKLAS2 and CTKLAS2Z and between CTKLAS2I and CTKLAS2J) and vertical arrows (going into top of box) to show transfer of control.

*At least it is not unambiguous as to whether there is a path between CTKLAS2 and CTKLASY or between CTKLAS2I adn CTKLASY, or both.

- Note: The revised hierarchical structure diagrams would obviously have different numbers for some boxes than those used in Section B.2. The latter was based on the given hierarchical structure diagrams as shown in Volume 2.

c. It was not clear in what sense lines with arrows and those without arrows were used in the hierarchical structure diagrams of Volume 2. If the use of arrows was to show transfer of control and the absence of arrows to tie together routines of the same module, the method would be inconsistent because there are no arrows on the lines which connect CTKLAS2 to CTKLAS2(A-I) in figure 4.2 of Volume 2.

E. Inter-Module Message Tables

These tables, such as the one on page 4-34, figure 4.4, Volume 2, should indicate the page number of the flowchart of the referenced procedure (routine).

F. Configurations

The hardware and configuration to which 6.0/.20 applies should be defined in each volume.

G. Patch Listings

Patch listings in Volume 1 should have column headings.

H. Audit Comments

Although we do not agree with the comment on page A-1. Volume 2 that, ". . . the module is readily understandable even though it is non-modular," we do feel that this is a valuable part of maintenance documentation. Perhaps this section could be expanded.

MESSAGE ENTRY

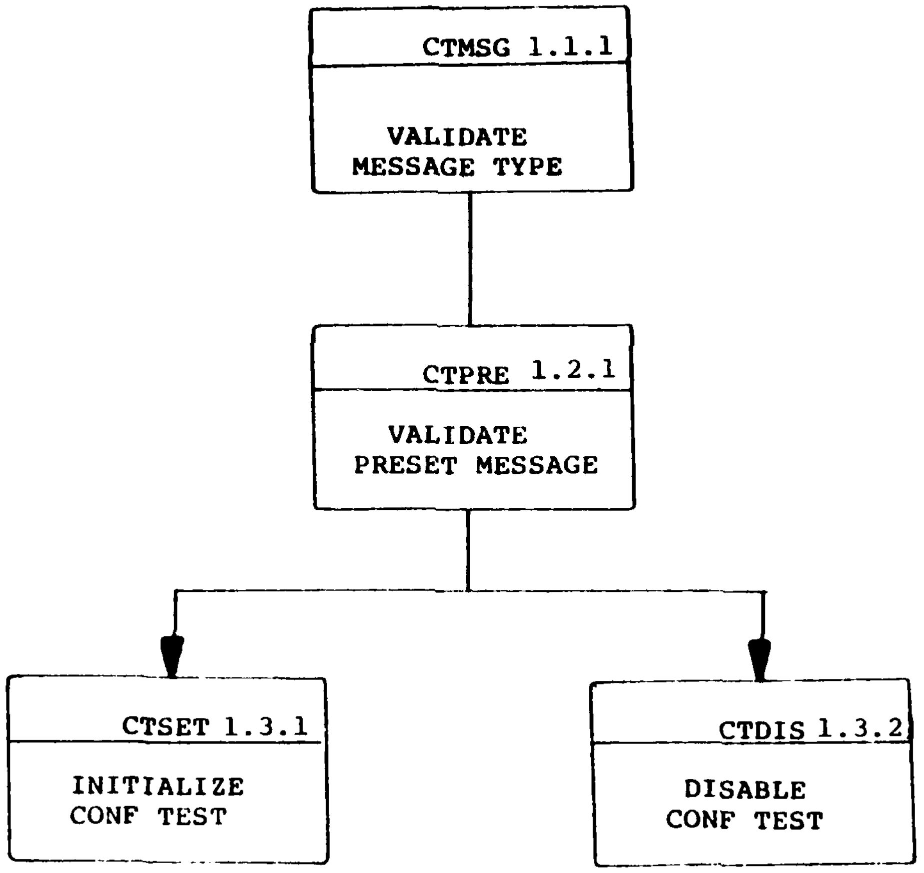


FIGURE 4.2 CT Hierarchical Structure (1 of 5)

Page 4-4

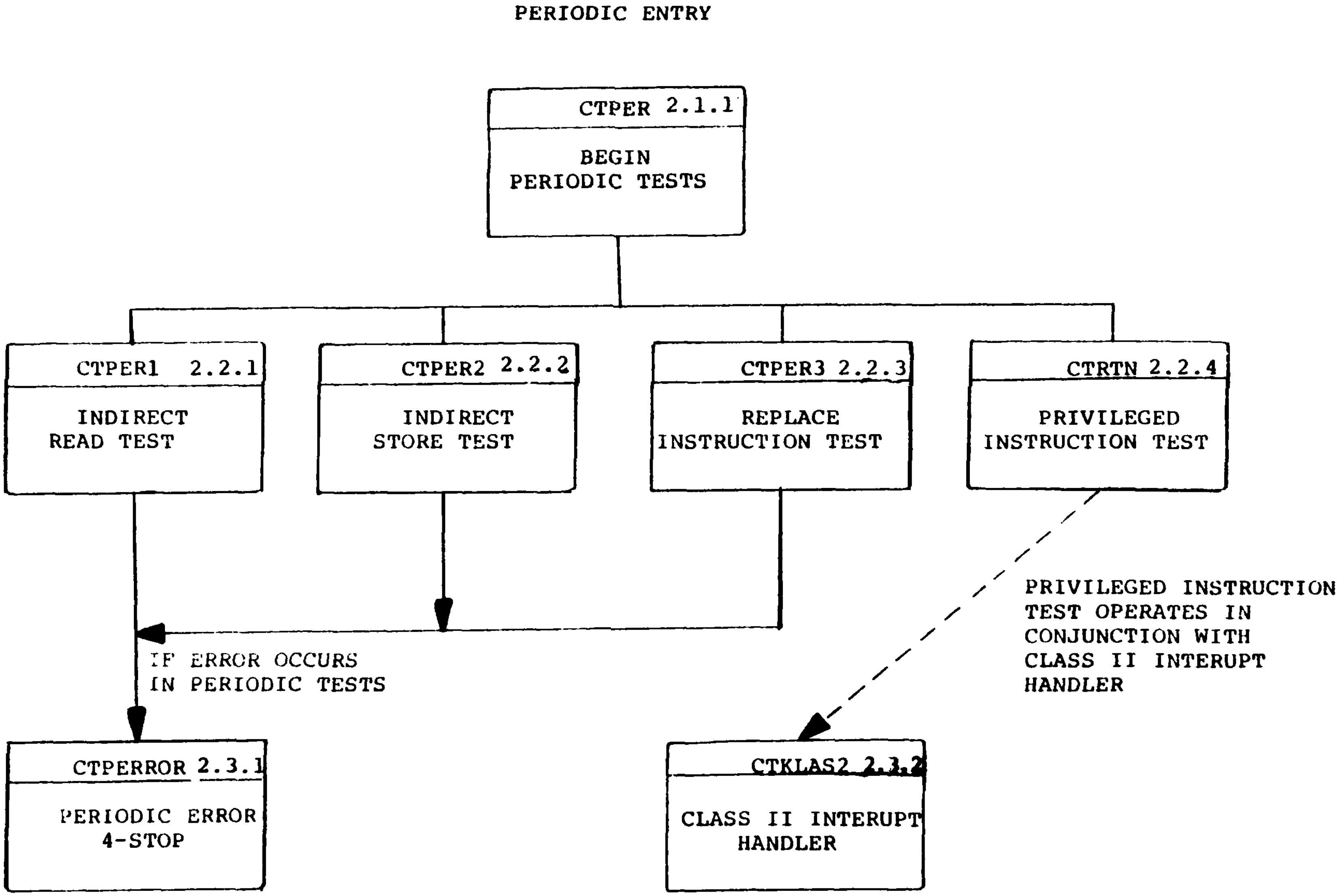


FIGURE 4.2 CT Hierarchical Structure (2 of 5)
Page 4-5

DEFERRED ENTRY

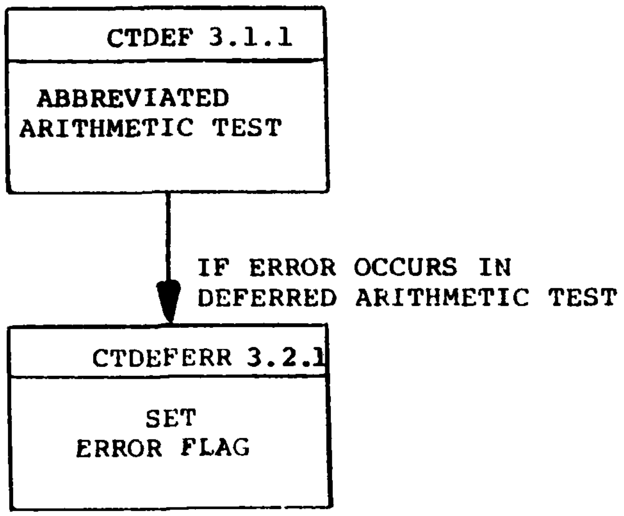

CTDEF 3.1.1
ABBREVIATED ARITHMETIC TEST
IF ERROR OCCURS IN DEFERRED ARITHMETIC TEST
CTDEFERR 3.2.1
SET ERROR FLAG

FIGURE 4.2 CT Hierarchical Structure (3 of 5)
Page 4-6

CLASS II INTERRUPT ENTRY

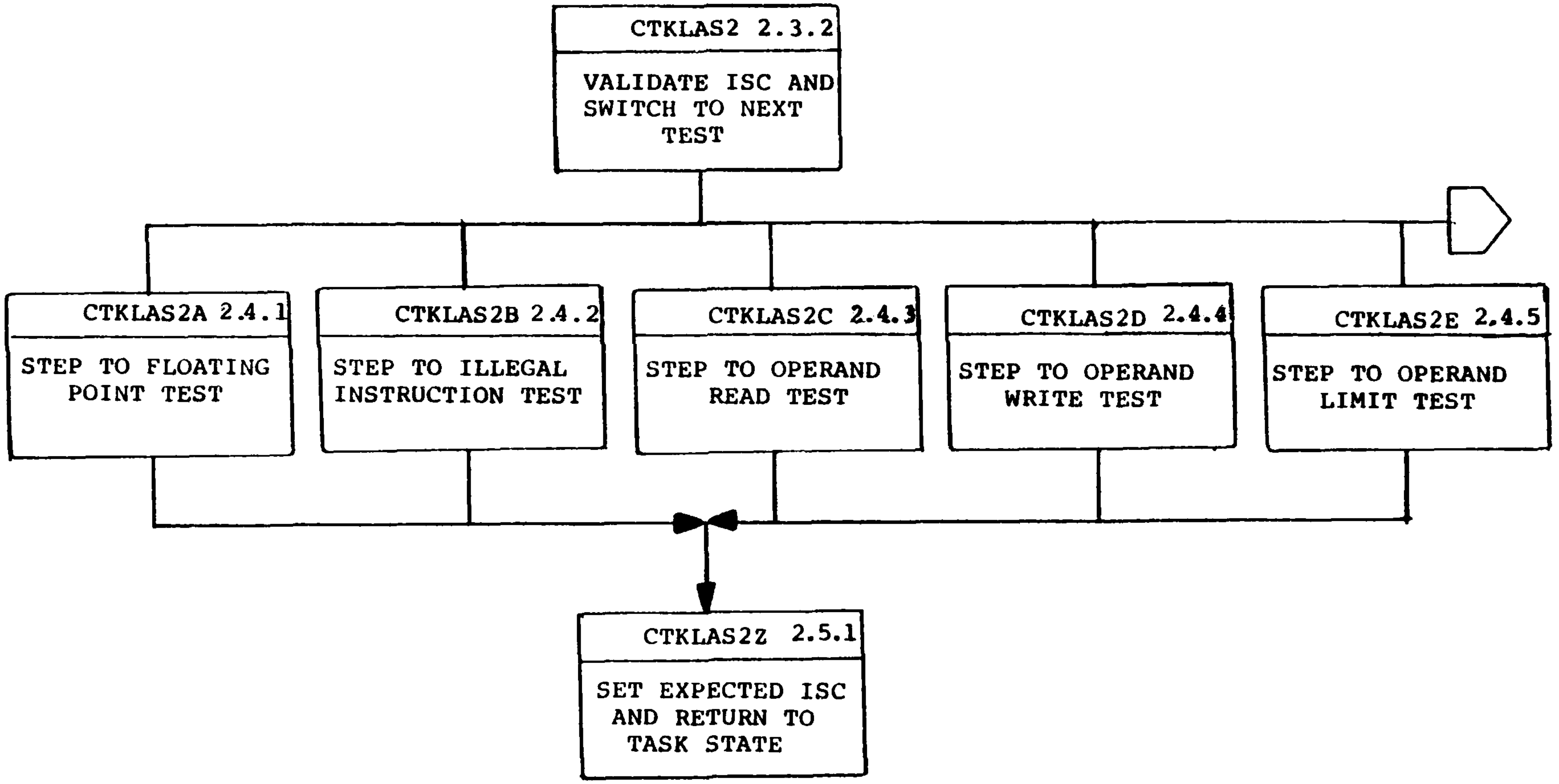

CTKLAS2 2.3.2
VALIDATE ISC AND SWITCH TO NEXT TEST
CTKLAS2A 2.4.1
STEP TO FLOATING POINT TEST
CTKLAS2B 2.4.2
STEP TO ILLEGAL INSTRUCTION TEST
CTKLAS2C 2.4.3
STEP TO OPERAND READ TEST
CTKLAS2D 2.4.4
STEP TO OPERAND WRITE TEST
CTKLAS2E 2.4.5
STEP TO OPERAND LIMIT TEST
CTKLAS2Z 2.5.1
SET EXPECTED ISC AND RETURN TO TASK STATE

FIGURE 4.2 CT Hierarchical Structure (4 of 5)
Page 4-7

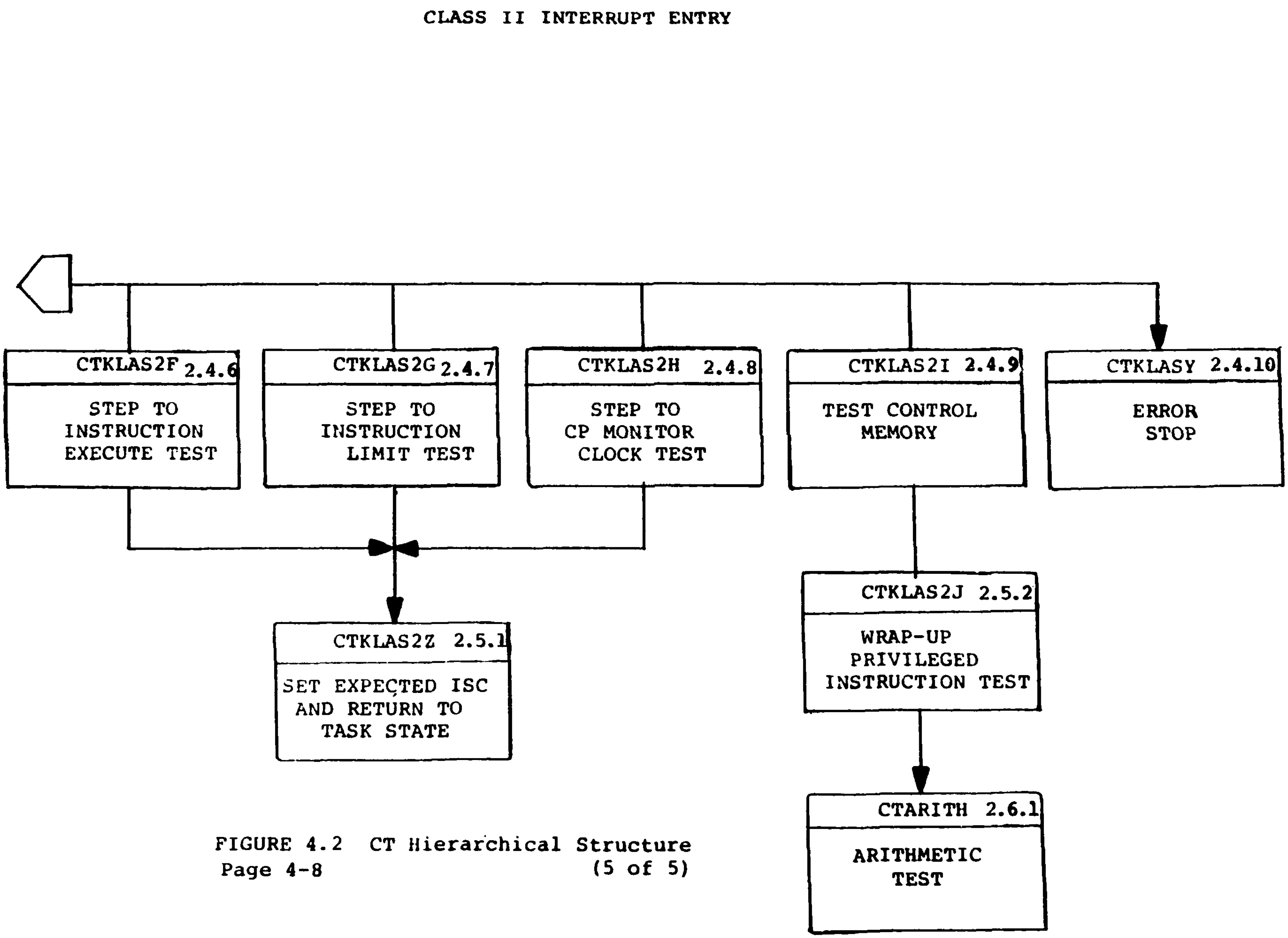


FIGURE 4.2 CT Hierarchical Structure
Page 4-8 (5 of 5)

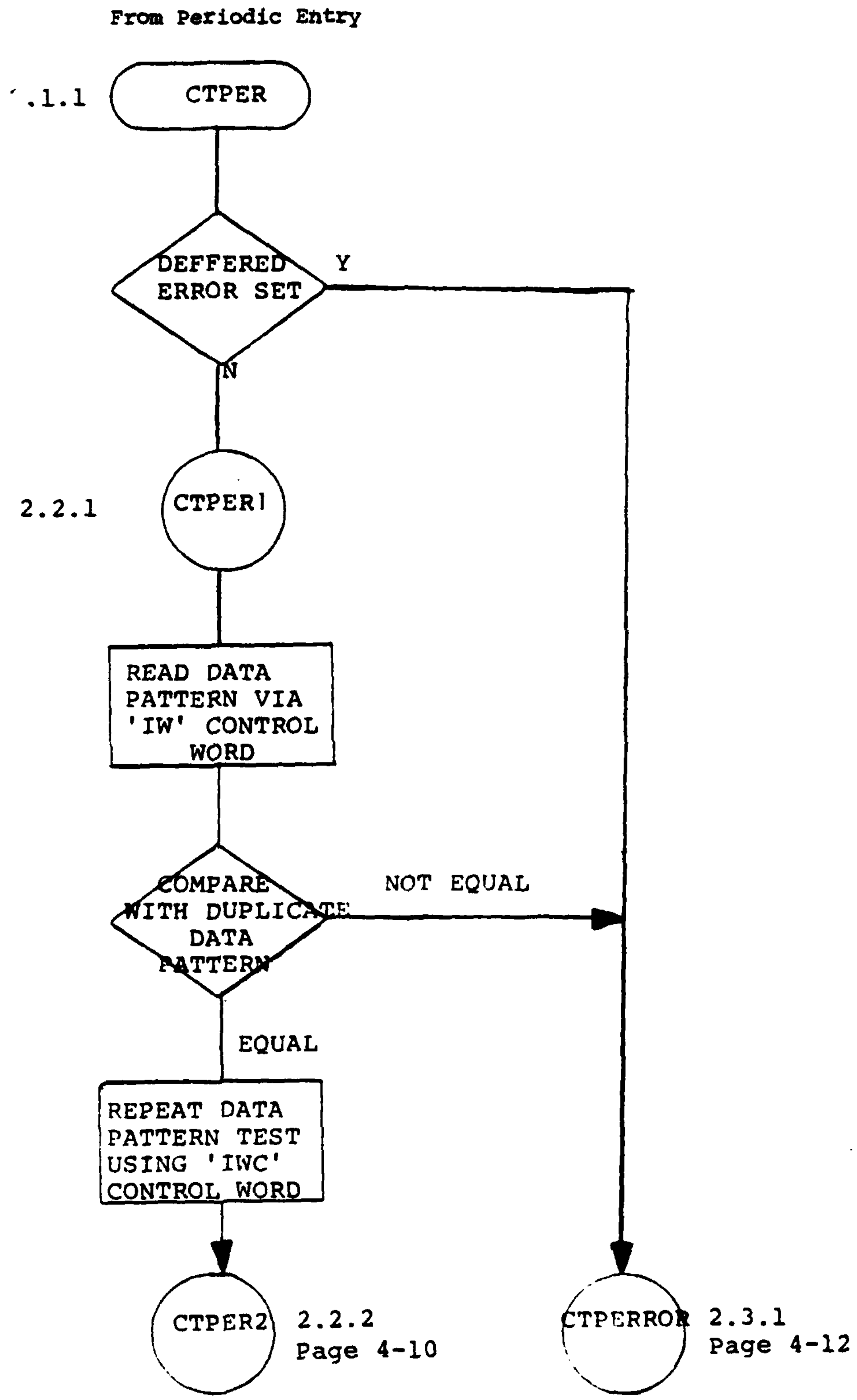
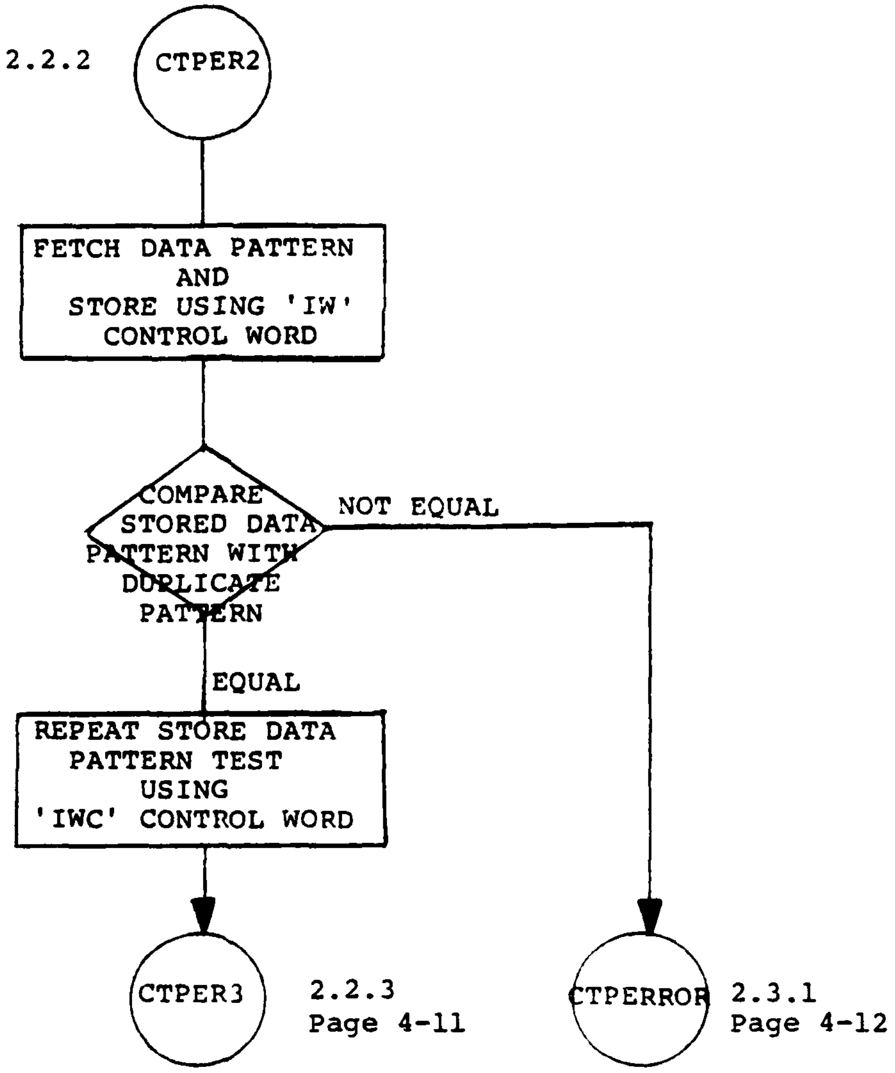

From Periodic Entry
´.1.1
CTPER
DEFFERED ERROR SET
Y
N
2.2.1
CTPER1
READ DATA PATTERN VIA 'IW' CONTROL WORD
COMPARE WITH DUPLICATE DATA PATTERN
NOT EQUAL
EQUAL
REPEAT DATA PATTERN TEST USING 'IWC' CONTROL WORD
CTPER2
2.2.2
Page 4-10
CTPERROR
2.3.1
Page 4-12

FIGURE 4.3 CT Flowcharts (1 of 25)
Page 4-9

From Page 4-9


2.2.2
CTPER2
FETCH DATA PATTERN AND STORE USING 'IW' CONTROL WORD
COMPARE STORED DATA PATTERN WITH DUPLICATE PATTERN
NOT EQUAL
EQUAL
REPEAT STORE DATA PATTERN TEST USING 'IWC' CONTROL WORD
CTPER3
2.2.3
Page 4-11
CTPERROR
2.3.1
Page 4-12

FIGUPE 4.3 CT Flowcharts (2 of 25)
Page 4-10

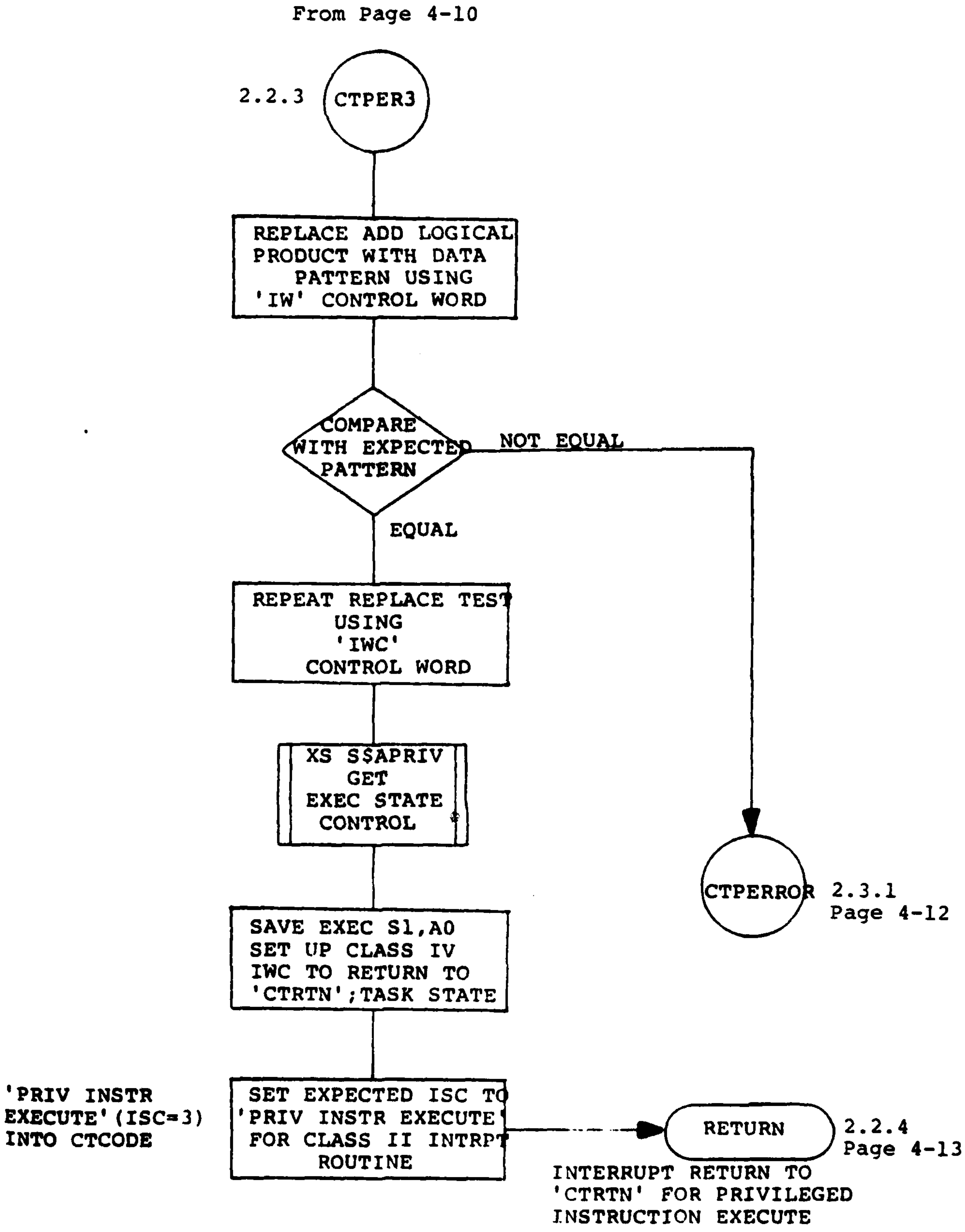

From Page 4-10
2.2.3
CTPER3
REPLACE ADD LOGICAL PRODUCT WITH DATA PATTERN USING 'IW' CONTROL WORD
COMPARE WITH EXPECTED PATTERN
NOT EQUAL
EQUAL
REPEAT REPLACE TEST USING 'IWC' CONTROL WORD
XS S$APRIV GET EXEC STATE CONTROL
CTPERROR
2.3.1
Page 4-12
SAVE EXEC S1,A0 SET UP CLASS IV IWC TO RETURN TO 'CTRTN';TASK STATE
'PRIV INSTR EXECUTE'(ISC=3) INTO CTCODE
SET EXPECTED ISC TO 'PRIV INSTR EXECUTE' FOR CLASS II INTRPT ROUTINE
RETURN
2.2.4
Page 4-13
INTERRUPT RETURN TO 'CTRTN' FOR PRIVILEGED INSTRUCTION EXECUTE

FIGURE 4.3 CT Flowcharts (3of 25)
Page 4-11

From Pages 4-9,10,11

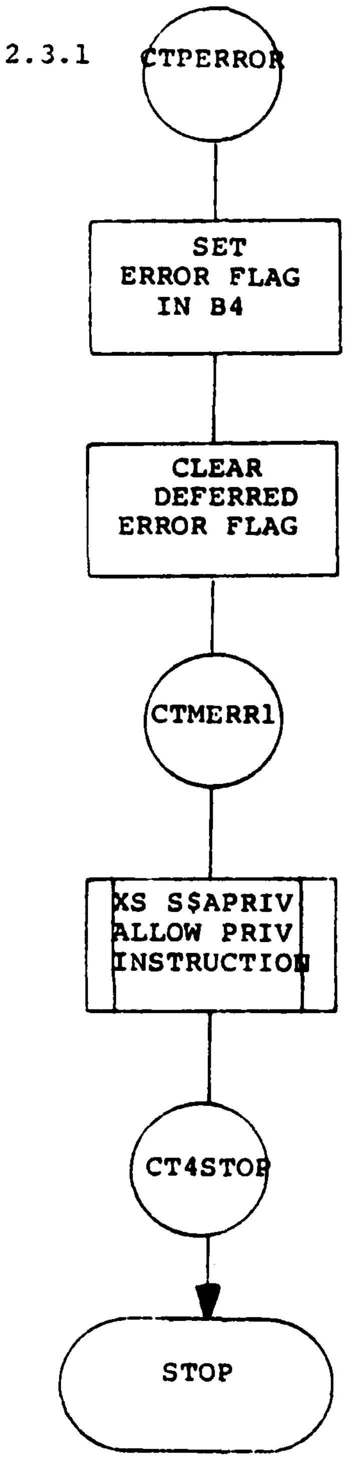


FIGURE 4.3 CT Flowcharts (4 of 25)
Page 4-12

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        CTA                                   CMS-2 ASSEMBLER                                                 PAGE    6

  ID  F N AC  ADDR   F  A K B I   SY      LABEL    OP CODE   OPERAND                 COMMENTS                     SEQUENCE    Flowchart I.B
                                                                                                                           At        To
  00191       000037 23 0 3 0 0 000521             SB        B0,CTERFLAG,K3          . CLEAR ERROR FLAG           CTM1003/1
  00192       000040 07 0 0 0 0 000004             XS        SSEXIT                  . EXIT                       CTM10038
  00193       000041 07 0 0 0 0 000104    CTDIS    XS        SSDELPER                . DELETE PERIODIC            CTM10040
  00194       000042 07 0 0 0 0 000110             XS        SSDELDEF                . DELETE DEFERRED            CTM10041
  00195       000043 10 0 0 0 0 0 00744            LA        AO,CTERMSGE,K0,B0,S0 ,                               E15682
  00196       000044 10 1 0 0 0 000004             LA        A1,4                    .                            E15682
  00197       000045 07 0 0 0 0 000203             XS        SSOHFS                  .                            E15682
  00198       000046 07 0 0 0 0 000004             XS        SSEXIT                  . EXIT                       CTM10092
  00199       000047 20 4 0 0 0 000000    CTMERR   LB        F4,0                    . MESSAGE ENTRY FLAG         CTM10087
  00200       000050 07 0 0 0 0 000425    CTMERR1  XS        SSAPRIV                 . ENABLE PRIVELEGED INST.    CTM10091
  00201       000051 53 4 3 0 0 0 000051  CT4STOP  JSC       4,CT4STOP             . 4 STOP                       CTM10192
  00202                                         . ********** PERIODIC ENTRY                      **********.      CTM10104
  00203       000052 20 7 0 0 0 000001    CTPER    LB        B7,1                    . INDIRECT ADDRESSING TEST   CTM10105   2.1.1
  00217                                            ENDCS T   BRCONDF, CTFHOLD      . C-SWITCH END FIRED S U
  00218       000053 42 02 0 0 000521              AC        2,CTERFLAG              . CHECK DEFERRED ERROR       CTM101051
  00219       000054 53 0 1 0 0 0 000337           JNE       CTPERROR                . GO TO ERROR MESSAGE        CTM101052             2.3.1
  00220       000055 10 0 3 7 1 000475    CTPER1   LA        AO,*CTRDIDR1,K3,B7      . CHECK READ CLASS           CTM10106   2.2.1
  00221       000056 44 0 3 7 0 000477             C         AO,CTC1,K3,B7           . IS IT CORRECT              CTM10107
  00222       000057 53 0 1 0 0 0 000337           JNE       CTPERROR                . IF NOT GO TO ERROR         CTM10108              2.3.1
  00223       000060 52 7 1 0 0 0 000055           JBNZ      B7,CTPER1               . TEST BOTH IW AND IWC       CTM10109              2.2.1
  00224       000061 20 7 0 0 0 000001             LB        B7,1                    . CHECK STORE CLASS          CTM10110
  00225       000062 10 0 3 7 0 000473    CTPER2   LA        AO,CT2SPAT,K3,B7        .                            CTM10111   2.2.2
  00226       000063 24 0 3 7 1 000503             SA        AO,*CTIDRV1,K3,B7       . TRY IT                     CTM10112
  00227       000064 10 0 3 7 0 000505             LA        AO,CTV1,K3,B7           . FETCH WHOLE WORD           CTM10113
  00228       000065 44 0 3 7 0 000501             C         AO,CTC2,K3,B7           . CHECK IT                   CTM10114
  00229       000066 53 0 1 0 0 0 000337           JNE       CTPERROR                . IS IT CORRECT              CTM10115              2.3.1
  00230       000067 52 7 1 0 0 0 000062           JBNZ      B7,CTPER2               . GET BOTH                   CTM10116              2.2.2
  00231       000070 71 7 2 7 0                    HAN       A7,A7                   . CLEAR MASK                 CTM10117
  00232       000071 20 7 0 0 0 000001             LB        B7,1                    . TEST REPLACE CLASS         CTM10118
  00233       000072 10 0 3 7 0 000473    CTPER3   LA        AO,CT2SPAT,K3,B7        .                            CTM10119   2.2.3
  00234       000073 03 7 4 7 1 000503             RALP      A7,*CTIDRV1,B7          . TRY IT                     CTM10120
  00235       000074 10 0 3 7 0 000505             LA        AO,CTV1,K3,B7           . CHECK IT                   CTM10121
  00236       000075 44 0 3 7 0 000501             C         AO,CTC2,K3,B7           .                            CTM10122
  00237       000076 53 0 1 0 0 0 000337           JNE       CTPERROR                . IS IT CORRECT              CTM10123              2.3.1
  00238       000077 52 7 1 0 0 0 000072           JBNZ      B7,CTPER3               . TRY BOTH                   CTM10124              2.2.3
  00239                                         . **** PRIVILEGED INSTRUCTION TEST                                CTM10125
  00240       000100 07 0 0 0 0 000425             XS        SSAPRIV                 . GET EXEC STATE CONTROL     CTM10126
  00241       000101 54 70 0 0 000510              LCI       070,CTASR1              . SET ALL INTERRUPT LOCKOUTS CTM10127
  00242       000102 57 00 0 0 000514              SCI       0,CTINTEM3              . SAVE EXEC AU               CTM10128
  00243       000103 57 44 0 0 000512              SCI       044,CTINTEM1            . SAVE CLASS II ICW          CTM10129
  00244       000104 55 44 0 0 000516              LCI       044,CTINTEN1            . SET UP ICW                 CTM10130
  00245       000105 57 21 0 0 000513              SCI       021,CTINTEM2            . SAVE EXEC SI               CTM10131
  00246       000106 60 21 0 0                     HSCT      021,A0                  . SET UP EXEC SI             CTM10132
  00247       000106 61 21 0 1                     HLCI      021,A0                  .                            CTM10133
  00248       000107 55 55 0 0 000511              LCI       055,CTASR2              . PREPARE TO GO TO TASK      CTM10134
  00249       000110 55 57 0 0 000515              LCI       057,CTPSTA              .                            CTM10135
  00250       000111 23 0 3 0 0 000524             SB        B0,CTCOUNT1,K3          . CLEAR INTERRUPT COUNTER    CTM10136
  00251       000112 10 0 0 0 0 000003             LA        A0,3                    .                            CTM10137
  00252       000113 24 0 3 0 0 000525             SA        AO,CTCHDF,K3            .                            CTM10138
  00253       000114 07 0 5 0 0 0 00001            IH                                . TO TASK STATE              CTM10139
  00254       000115 07 0 2 0 0 000000    CTRIM    PEI       0                       . EXECUTE PRIVILEGED INSTRUCT CTM10140  2.2.4
  00255       000116 07 0 3 0 0 000000             LIH       0                       .                            CTM10141
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                CTA                                        CMS-2  ASSEMBLER                                                    PAGE     7

  ID   FOR AL  ADDR   F   A K B I    SY      LABEL    OP CODE    OPERAND                 COMMENTS                    SEQUENCE

 00256         000117 07  0 4 0 0 000000               IO         0                       .                            CTMI0192
 00257         000120 07  0 5 0 0 0 00000              IR         0                       .                            CTMI0193
 00258         000121 53  4 2 0 0 0 000000             RJSC       4                       .                            CTMI0194
 00259         000122 53  4 3 0 0 0 000000             JSC        4                       .                            CTMI0195
 00260         000123 54  20 0 0 000000                LCT        020                     .                            CTMI0196
 00261         000124 54  60 0 0 000000                LCT        060                     .                            CTMI0197
 00262         000125 54  70 0 0 000000                LCT        070                     .                            CTMI0198
 00263         000126 55  00 0 0 000000                LCI        0                       .                            CTMI0199
 00264         000127 56  20 0 0 000000                SCT        020                     .                            CTMI0150
 00265         000130 56  40 0 0 000000                SCT        040                     .                            CTMI0151
 00266         000131 56  70 0 0 000000                SCT        070                     .                            CTMI0152
 00267         000132 60  20 0 0                       HSCT       020                     .                            CTMI0154
 00268         000132 74  0 3 0 0                      HNO                                .                            CTMI0153
 00269         000133 60  60 0 0                       HSCT       060                     .                            CTMI0156
 00270         000133 74  0 3 0 0                      HNO                                .                            CTMI0155
 00271         000134 60  70 0 0                       HSCT       070                     .                            CTMI0158
 00272         000134 74  0 3 0 0                      HNO                                .                            CTMI0157
 00273         000135 60  00 0 1                       HSCI       A0                      .                            CTMI0160
 00274         000135 74  0 3 0 0                      HNO                                .                            CTMI0159
 00275         000136 61  20 0 0                       HLCT       020                     .                            CTMI0162
 00276         000136 74  0 3 0 0                      HNO                                .                            CTMI0161
 00277         000137 61  60 0 0                       HLCT       060                     .                            CTMI0164
 00278         000137 74  0 3 0 0                      HNO                                .                            CTMI0163
 00279         000140 61  70 0 0                       HLCT       070                     .                            CTMI0166
 00280         000140 74  0 3 0 0                      HNO                                .                            CTMI0165
 00281         000141 61  00 0 1                       HLCI       A0                      .                            CTMI0168
 00282         000141 74  0 3 0 0                      HNO                                .                            CTMI0167
 00283         000142 77  0 0 0 0                      HSIM       0                       .                            CTMI0170
 00284         000142 74  0 3 0 0                      HNO                                .                            CTMI0169
 00285         000143 77  0 4 0 0                      HPI                                .                            CTMI0172
 00286         000143 74  0 3 0 0                      HNO                                .                            CTMI0171
 00287         000144 77  0 5 0 0                      HAI                                .                            CTMI0174
 00288         000144 74  0 3 0 0                      HNO                                .                            CTMI0173
 00289         000145 77  0 6 0 0                      HALT                               .                            CTMI0176
 00290         000145 74  0 3 0 0                      HNO                                .                            CTMI0175
 00291         000146 77  0 6 0 1                      HAFI                               .                            CTMI0178
 00292         000146 74  0 3 0 0                      HNO                                .                            CTMI0177
 00293         000147 07  1 0 0 0 000000               IPI        0                       .                            CTMI0179
 00294         000150 07  0 1 0 0 000000               AEI        0                       .                            CTMI0180
 00295         000151 05  0 0 0 0 000517               DL         A0,CTONES               . GENERATE FLOATING          CTMI0181
 00296         000152 06  0 0 0 0 000517               FA         A0,CTONES               . POINT ERROR                CTMI0182
 00297         000153 0000000000                       *          0                       . GENERATE ILLEGAL INSTRUCTION CTMI0183
 00298         000154 10  0 3 0 0 4 00154   CTOP1      LI         A0,CTOP1,K3,,SCTTRAN4         . OPERAND READ ERR     CTMI0184
 00299         000155 24  0 3 0 0 0 00155   CTOP2      SA         A0,CTOP2,K3,,SCTTRAN0         . OPERAND WRITE ERR    CTMI0185
 00300         000156 24  0 3 0 0 5 00156   CTOP3      SA         A0,CTOP3,K3,,SCTTRAN5         . OPERAND LIMIT ERR    CTMI0186
 00301         000157 53  0 3 0 0 0 6 00163            J          $+1, , ,SCTTRAN6              .                      CTMI0187
 00302         000160 20  0 0 0 0 000000    CTOP4      LB         B0,0                          . INSTRUCTION EXECUTE  CTMI0188
 00303         000161 53  0 3 0 0 0 5 00162            J          $+1, , ,SCTTRAN5              .                      CTMI0189
 00304         000162 20  0 0 0 0 000000    CTOP5      LB         B0,0                          . INSTRUCTION LIMIT    CTMI0190
 00305         000163 53  0 3 0 0 0 000163  CTOP6      J          CTOP6                   . WAIT FOR INTERRUPT         CTMI0192
 00306                                        . *** INTERRUPT  ROUTINE FOR CLASS 2 ERRORS                              CTMI0193
 00307         000164 54  70 0 0 000510     CTKLAS2    LCT        070,CTASRI              . TO TASK REGISTERS,         CTMI0194
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                  CTA                                       CMS-2  ASSEMBLER                                        PAGE

  ID  FRN AC   ADDR  F   A K B I    SY       LABEL     OP CODE   OPERAND            COMMENTS                           SEQUENCE

→ 00308          000165 60 96 0 1                         HSCI      096,A0           . CHECK STATUS CODE                CTM10195
  00309          000166 20 0 0 0 0 000100                 LB        B0,0             .                                  CTM10196
  00310          000167 35 1 3 0 0 000524                 RI        A1,CTCOUNT1,K3   . INCREMENT TEST COUNT             CTM10197
  00311          000170 44 0 3 0 0 000525                 C         A0,CTCODE,K3     . IS STATUS CODE CORRECT           CTM10198
  00312                                         . *
  00313                                         . PPPPPPPPPPPPPPPPPPPPP**TI-H0070-01**PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
→ 00314          000171 53 0 1 0 0 0 000221               JNE       CTKLIPI          . NO, CHK IPI                      P
  00315                                         . PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
  00316                                         *
  00317          000172 44 1 0 0 0 000034                 C         A1,28            . ALL PRIVILEGED INSTRUCTIONS      CTM10200
  00318          000173 53 1 1 0 0 0 000227               JE        CTKLAS2A         .                                  CTM10201
  00319          000174 44 1 0 0 0 000035                 C         A1,29            . TRIED FLOATING POINT             CTM10202
  00320          000175 53 1 1 0 0 0 000231               JE        CTKLAS2B         .                                  CTM10203
  00321          000176 44 1 0 0 0 000036                 C         A1,30            . TRIED ILLEGAL INSTRUCTION        CTM10204
  00322          000177 53 1 1 0 0 0 000233               JE        CTKLAS2C         .                                  CTM10205
  00323          000200 44 1 0 0 0 000037                 C         A1,31            . TRIED OPERAND READ               CTM10206
  00324          000201 53 1 1 0 0 0 000235               JE        CTKLAS2D         .                                  CTM10207
  00325          000202 44 1 0 0 0 000040                 C         A1,32            . TRIED OPERAND WRITE              CTM10208
  00326          000203 53 1 1 0 0 0 000237               JE        CTKLAS2E         .                                  CTM10209
  00327          000204 44 1 0 0 0 000041                 C         A1,33            . TRIED OPERAND LIMIT              CTM10210
  00328          000205 53 1 1 0 0 0 000241               JE        CTKLAS2F         .                                  CTM10211
  00329          000206 44 1 0 0 0 000042                 C         A1,34            . TRIED INSTRUCTION EXECUTE        CTM10212
  00330          000207 53 1 1 0 0 0 000243               JE        CTKLAS2G         .                                  CTM10213
  00331          000210 44 1 0 0 0 000043                 C         A1,35            . TRIED INSTRUCTION LIMIT          CTM10214
  00332          000211 53 1 1 0 0 0 000246               JE        CTKLAS2H         .                                  CTM10215
  00333          000212 44 1 0 0 0 000044                 C         A1,36            . TRIED CP MONITOR CLOCK           CTM10216
  00334          000213 53 1 1 0 0 0 000252               JE        CTKLAS2I         .                                  CTM10217
→ 00335          000214 24 0 3 0 0 000525       CTKLAS22  SA        A0,CTCODE,K3     . SAVE NEXT EXPECTED STATUS CC     CTM10218
  00336          000215 60 97 0 1                         HSCI      097,A0           . UPDATE P-STONE                   CTM10219
  00337          000216 14 0 0 0 0 000001                 AA        A0,1             .                                  CTM10220
  00338          000217 61 97 0 1                         HLCI      097,A0           .                                  CTM10221
  00339          000220 07 0 5 0 0 0 00000                IR                         . TO NEXT TEST                     CTM10222
  00340                                         . *
  00341                                         . PPPPPPPPPPPPPPPPPPPPPPPPP**TI-H007 -01**PPPPPPPPPPPPPPPPPPPPPPPPPPPPP
→ 00342          000221 51 0 3 0 0 0 000335     CTKLIPI   JNZ       A0,CTKLAST       . ERROR IF NOT IPI                 P
  00343                                         . * LEGITIMATE IPI RECEIVED FROM OTHER PROCESSOR DURING THIS TEST        P
  00344                                         . * - REGENERATE THE IPI TO PREVENT LOSS                                 P
  00345          000222 07 0 0 0 0 000425                 XS        SSAPRIV          . ALLOW PRIV INSTR                 P
  00346          000223 07 0 0 0 0 000416                 XS        SACPNUM          . GET THIS PROCESSOR NUMBER        P
  00347          000224 61 11 0 0                         HLCY      011,A0           . FOR INDEX                        P
  00348          000225 02 0 2 1 0 000471                 AR        CTGENIPI,B1      . GEN IPI FOR THIS PROCESSOR       P
→ 00349          000226 53 0 3 0 0 0 000320               J         CTKL2TIT         . EXIT CL II INTERRUPT TEST        P
  00350                                         . PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
  00351                                         . *
  00352          000227 10 0 0 0 0 000001       CTKLAS2A  LA        A0,1             . FLOATING POINT STATUS CODE       CTM10223
  00353          000230 53 0 3 0 0 0 000214               J         CTKLAS22         .                                  CTM10224
  00354          000231 10 0 0 0 0 000002       CTKLAS2B  LA        A0,2             . ILLEGAL INSTRUCTION              CTM10225
  00355          000232 53 0 3 0 0 0 000214               J         CTKLAS22         .                                  CTM10226
  00356          000233 10 0 0 0 0 000006       CTKLAS2C  LA        A0,6             . OPERAND READ                     CTM10227
  00357          000234 53 0 3 0 0 0 000214               J         CTKLAS22         .                                  CTM10228
  00358          000235 10 0 0 0 0 000011       CTKLAS2D  LA        A0,011           . OPERAND WRITE                    CTM10229
  00359          000236 53 0 3 0 0 0 000214               J         CTKLAS22         .                                  CTM10230
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         CTA                                CMS-2  ASSEMBLER                                                  PAGE     9

ID  F R IC   ADDR   F  A K B I    SY      LABEL    OP CODE    OPERAND                COMMENTS                          SEQUENCE

  00360      000237 10 0 0 0 0 000012   CTKLAS2E  LA       A0,U12               . OPERAND LIMIT                   CTM10231
  00361      000240 53 0 3 0 0 0 000214           J        CTKLAS22             .                                 CTM10232
  00362      000241 10 0 0 0 0 000015   CTKLAS2F  LA       A0,U15               . INSTRUCTION EXECUTE             CTM10233
  00363      000242 53 0 3 0 0 0 000214           J        CTKLAS22             .                                 CTM10234
  00364      000243 55 47 0 0 000522    CTKLAS2G  LCI      047,CTDUMPN1         . RESTORE S1 TO P-STORE           CTM10235
  00365      000244 10 0 0 0 0 000016             LA       A0,U16               . INSTRUCTION LIMIT               CTM10236
  00366      000245 53 0 3 0 0 0 000214           J        CTKLAS22             .                                 CTM10237
  00367      000246 55 47 0 0 000523    CTKLAS2H  LCI      047,CTDUMPN2         . RESTORE S1 TO P-STORE           CTM10238
  00368      000247 10 0 0 0 0 000017             LA       A0,U17               . CP MONITOR CLOCK                CTM10239
  00369      000250 55 10 0 0 000526              LCI      010,CTCLK            . LOAD CP MONITOR CLOCK           CTM10191
  00370      000251 53 0 3 0 0 0 000214           J        CTKLAS22             .                                 CTM10240
  00371      000252 20 7 0 0 0 000100   CTKLAS2I  LB       B7,U100             . SAVE EXEC REGISTERS             CTM10241
  00372      000253 20 1 0 0 0 000000             LB       B1,U                 .                                 CTM102411
  00373      000254 23 0 3 0 0 000521             SB       B0,CTERFLAG,K3       . CLEAR FLAG                      CTM102412
  00374      000255 07 7 6 0 0 000001             RP       7,1                  .                                 CTM10242
  00375      000256 57 00 1 0 000531              SCI      A0,CTREGSTR,B1       .                                 CTM10243
  00376      000257 20 7 0 0 0 000010             LB       B7,U10                . LOAD WITH ZEROES ES21          CTM10244
  00377      000260 07 7 6 0 0 000000             RP       7                    .                                 CTM10245
  00378      000261 55 00 0 0 000527              LCI      A0,CTOMPAT           .                                 CTM10246
  00379      000262 20 7 0 0 0 000067             LB       B7,U67                          .                      **ES21**
  00380      000263 07 7 6 0 0 000000             RP       7                               .                      **ES21**
  00381      000264 55 11 0 0 000527              LCI      011,CTOMPAT                     .                      **ES21**
  00382      000265 20 7 0 0 0 000100             LB       B7,U100              . STORE AWAY                      CTM10247
  00383      000266 20 1 0 0 0 000000             LB       B1,U                 .                                 CTM102471
  00384      000267 07 7 6 0 0 000001             RP       7,1                  .                                 CTM10248
  00385      000270 57 00 1 0 000631              SCI      A0,CTEMPSTR,B1       .                                 CTM10249
  00386      000271 20 7 0 0 0 000100             LB       B7,U100              . CHECK THEM                      CTM10250
  00387      000272 23 0 3 0 0 000641             SB       B0,CTEMPSTR+U10,K3    .                              **ES21**
  00388      000273 20 1 0 0 0 000000             LB       B1,U                 .                                 CTM102501
  00389      000274 07 0 6 0 0 000001             RP       0,1                  .                                 CTM10251
  00390      000275 10 0 3 1 0 000631             LA       A0,CTEMPSTR,K3,B1    .                                 CTM10252
→ 00391      000276 52 7 1 0 0 0 000335           JBNZ     B7,CTKLASY           . GO IF ERROR                     CTM10253
  00392      000277 20 7 0 0 0 000100             LB       B7,U100              . CHECK WITH ONES                 CTM10254
  00393      000300 07 7 6 0 0 000000             RP       7                    .                                 CTM10255
  00394      000301 55 00 0 0 000517              LCI      A0,CTONES            .                                 CTM10256
  00395      000302 20 7 0 0 0 000100             LB       B7,U100              . TO TEMPORARY STORAGE            CTM10257
  00396      000303 20 1 0 0 0 000000             LB       B1,U                 .                                 CTM102571
  00397      000304 07 7 6 0 0 000001             RP       7,1                  .                                 CTM10258
  00398      000305 57 00 1 0 000631              SCI      A0,CTEMPSTR,B1       .                                 CTM10259
  00399      000306 20 7 0 0 0 000100             LB       B7,U100              . CHECK THEM                      CTM10260
  00400      000307 20 1 0 0 0 000000             LB       B1,U                 .                                 CTM102601
  00401      000310 07 7 6 0 0 000001             RP       7,1                  .                                 CTM10261
  00402      000311 14 0 3 1 0 000631             AA       A0,CTEMPSTR,K3,B1    .                                 CTM10262
  00403      000312 13 0 3 0 0 000535             ANA      A0,CTCONST1,K3       .                                 CTM10263
→ 00404      000313 51 0 3 0 0 0 000335           JNZ      A0,CTKLASY           .                                 CTM10264
  00405      000314 20 1 0 0 0 000000   CTKLAS2J  LB       B1,U                 . RESTORE ORIGINAL CONTENTS       CTM10265
  00406      000315 20 7 0 0 0 000100             LB       B7,U100             .                                 CTM10266
  00407      000316 07 7 6 0 0 000001             RP       7,1                  .                                 CTM10267
  00408      000317 55 00 1 0 000531              LCI      A0,CTREGSTR,B1       .                                 CTM10268
  00409                                 . ***PERIODIC TESTS PASSED                                                 CTM10269
  00410                                 . *
  00411                                 . PPPPPPPPPPPPPPPPPPPPPPPPP**TI-HO07 -01**PPPPPPPPPPPPPPPPPPPPPPPPPP P
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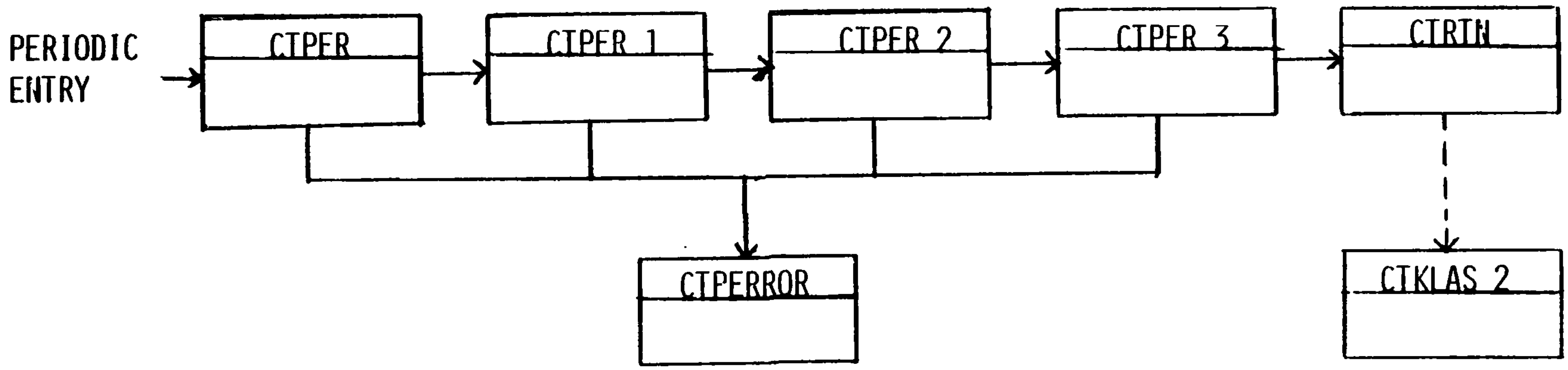
          CTA                                    CMS-2 ASSEMBLER                                                        PAGE

ID   E R AC  ADDR   F  A K B I     SY        LABEL     OP CODE   OPERAND            COMMENTS                          SEQUENCE

00412                                        CTKL2XIT,                                                                P
00413                                        . PPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
00414                                        . .
00415        000320 55 00 0 0 000514                   LCI       A0,CTINTEM3        . RESTORE EXEC REGISTERS          CTM10270
00416        000321 55 44 0 0 000512                   LCI       044,CTINTEM1       .                                 CTM10271
00417        000322 55 21 0 0 000513                   LCI       021,CTINTEM2       .                                 CTM10272
00418        000323 55 45 0 0 000517                   LCI    044,CTASK             . ASK = 0                         CTM102721
00419        000324 42 00 0 0 000521                   BC     0,CTERFLAG            . SEND ERROR MESSAGE              CTM102722
00420        000325 53 1 1 0 0 0 000327                JE     CTXIT0                . NO-JUMP                         CTM102723
00421        000326 55 45 0 0 000510                   LCI    045,CTASK1            . ASK MAINTAIN LOCKOUT            CTM102724
00422                                        CTXIT0    .         COMPLETE STATE SWITCH                                CTM102725
00423        000327 55 47 0 0 000731                   LCI       047,CTPSTRM        . STATE                           CTM10274
00424        000330 07 0 5 0 0 0 000000                IR                           . GO TO TASK                      CTM10275
00425        000331 42 00 0 0 000521         CTXIT     BC        0,CTERFLAG         . NEED ERROR MESSAGE              CTM10276
00426        000332 53 0 1 0 0 0 000337                JNE       CTPERROR           .                                 CTM10277
00427        000333 52 1 0 0 0 0 000415                LBJ       B1,CTARITH         .                                 **EISEN2**
00428        000334 07 0 0 0 0 000004        CTXIT1    XS        SSEXIT             . EXIT                            CTM10278
00429        000335 53 4 3 0 0 0 000051      CTKLASY   JSC       4,CT4STOP          . 4 STOP ON ERROR DETECTION       CTM10279
00430        000336 53 0 3 0 0 0 000314                J         CTKLAS2            . FINISH RESTORING REGISTERS,     CTM10280
00431        000337 20 4 0 0 0 000005        CTPERROR  L4        04,5               . SET FLAG                        CTM10281
00432        000340 32 02 0 0 000521                   BZ        2,CTERFLAG         . CLEAR DEFERRED ERROR            CTM102811
00433        000341 53 0 3 0 0 0 000056                J         CTMERR1            . PICK ERROR MESSAGE              CTM10282
00434        000342 00000002000              CTDEFSTR  +02000                       . 1 SEC. BETWEEN SLICES           CTM102821
00435        000343 00000024000                        +024000                      . 10 SEC. BETWEEN JOBS            CTM102822
00436        000344                                    RES + 34                     . DEFERRED SAVE AREA              CTM102823
00437        000400 05 0 0 0 0 000473        CTDEF     DL        A0,CT25PAT         .                                 CTM10303
00438        000401 71 2 2 4 0                         HAN       A2,A2              .                                 CTM10304
00439        000401 64 3 0 40                          HRZ       A3,32              .                                 CTM10305
00440        000402 71 2 1 0 0                         HA        A2,A0              .                                 CTM10306
00441        000402 71 3 2 1 0                         HAN       A3,A1              .                                 CTM10307
00442        000403 70 3 2 0 0                         HCP       A3                 .                                 CTM10308
00443        000403 61 04 0 0                          HLCT      A4,A0              .                                 CTM10309
00444        000404 61 05 1 0                          HLCT      A5,A1              .                                 CTM10310
00445        000404 74 0 4 2 0                         HC        A0,A2              .                                 CTM10311
00446        000405 53 0 1 0 0 0 000413                JNE       CTDEFERR           .                                 CTM10312
00447        000406 74 3 4 5 0                         HC        A3,A5              .                                 CTM10313
00448        000407 53 0 1 0 0 0 000413                JNE       CTDEFERR           .                                 CTM10314
00449        000410 71 2 2 4 0                         HAN       A2,A4              .                                 CTM10315
00450        000410 71 3 2 5 0                         HAN       A3,A5              .                                 CTM10316
00451        000411 56 2 3 0 0 0 000413                DJNZ      A2,CTDEFERR        .                                 CTM10317
00452        000412 07 0 0 0 0 000004                  XS        SSEXIT             .                                 CTM10320
00453        000413 33 01 0 0 000521         CTDEFERR  BS        01,CTERFLAG        . SET ERROR FLAG                  CTM10321
00454        000414 07 5 0 0 0 000004                  XS        SSEXIT             .                                 CTM10322
00455                                        CTARITH   . ARITHMETIC TEST            .                                 **EISEN2**
00456        000415 05 0 0 0 0 000473                  DL        A0,CT25PAT         .                                 **EISEN2**
00457        000416 05 2 0 0 0 000473                  DL        A2,CT25PAT         .                                 **EISEN2**
00458        000417 05 4 0 0 0 000473                  DL        A4,CT25PAT         .                                 **EISEN2**
00459        000420 05 6 0 0 0 000473                  DL        A6,CT25PAT         .                                 **EISEN2**
00460        000421 63 0 0 40                          MULC      A0,32              .                                 **EISEN2**
00461        000421 74 0 4 7 0                         HC        A0,A7              .                                 **EISEN2**
00462        000422 53 0 1 0 0 0 000477                JNE       CTMERR2            .                                 **EISEN2**
00463        000423 63 2 0 41                          MULC      A2,33              .                                 **EISEN2**
```



REVISED FIGURE 4.2 CT HIERARCHICAL STRUCTURE (2 OF 5)
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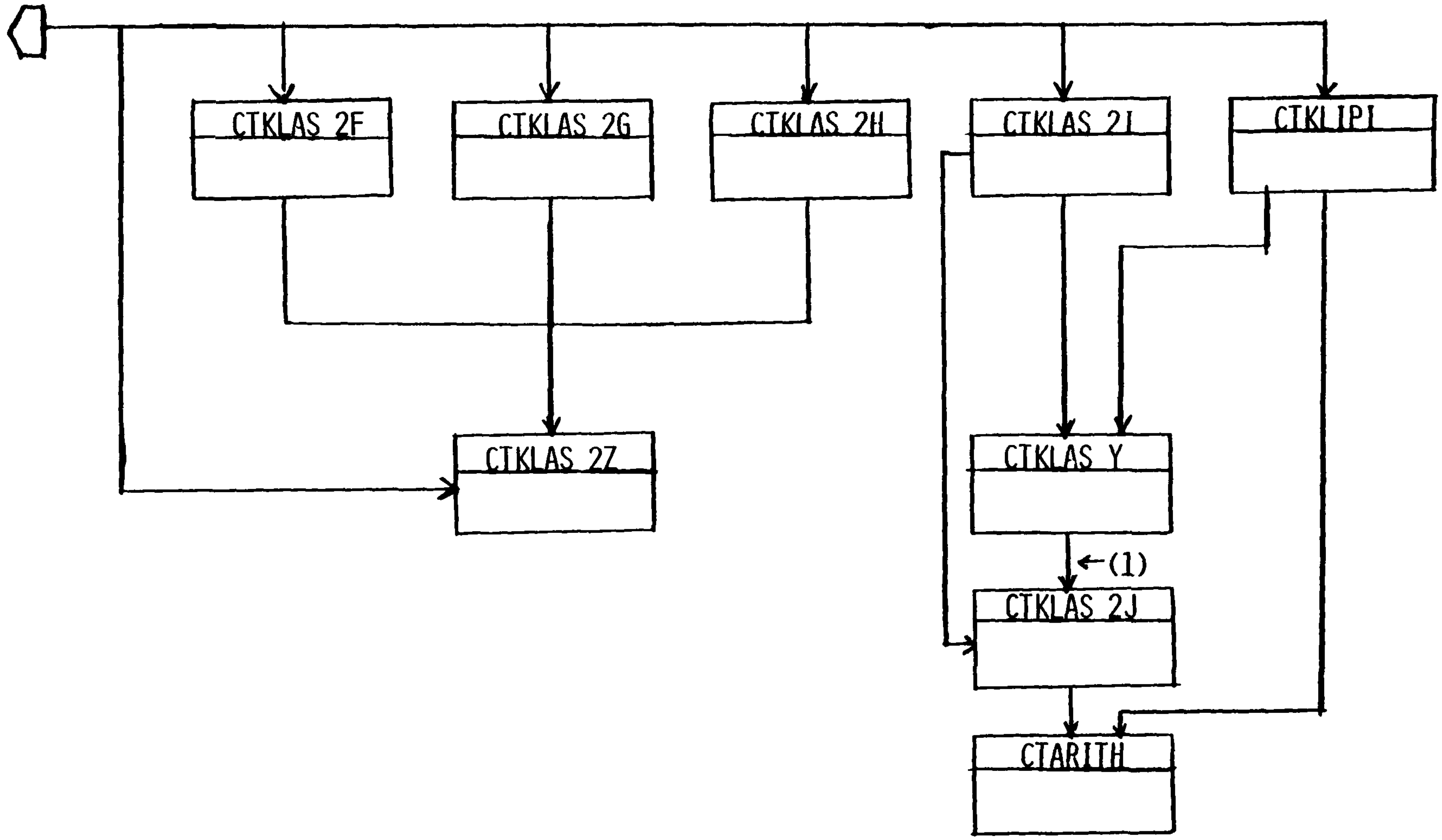

(1) Used only when a 4 stop condition does not exist.

REVISED FIGURE 4.2 CT HIERARCHICAL STRUCTURE (5 OF 5)
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REFERENCES

1. Oxman, Steven W., "Fiscal Year 1979 CCSMA System-Level Software Maintenance Approach and Transition Plan," March 20, 1979, (Revision E), Software Systems Department, Trident, CCSMA, New port, RI.

2. Oxman, Steven W., "The Testing of the Trident Command and Control System," Workshop on Software Testing and Test Documentation, December 1978, Digest.

3. Chapin, Ned, "Flowcharting with the ANSI Standard: A Tutorial," Computing Surveys, ACM, June 1970, Volume 2, No. 2.

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